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ABSTRACT

A materials science and technology (MST) program was developed at Richland High School (Washington) and pilot tested at seven sites in Washington and Oregon. The program created partnerships between science and vocational education teachers at Richland High and Battelle Pacific Northwest Laboratories, and then was expanded to include other high schools, a college, a university, and other industrial laboratories to train teachers to teach materials technology to students. This document describes the program and its pilot sites, provides a course description and course philosophy, outlines course content, lists student learning objectives, and suggests an instructional approach. (KC)

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# Materials Science and Technology

A preview of an exemplary high school course where students explore new frontiers of scientific and vocational education know-how

A cooperative project of:

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Central Washington University
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Richland Public Schools
Tri-Cities Area Vocational Administration
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# Materials science and technology

*A world of experimenting, creating, designing, and building*

## Course Description

"Students use a wide variety of written resources, including current scientific journals, technical reports, and textbooks to obtain information about the materials studied."

Through the unique combination of the academic disciplines of chemistry, physics, and engineering comes the study of materials science and technology (MST).

Materials are critical everywhere in our modern technological world, and tomorrow's workers and citizens need explicit knowledge about these materials. The introduction of materials science and technology into the high school is necessary to better equip students to meet the challenge of our nation's future.

This introductory course is designed to appeal to a broad range of students by combining hands-on experimenting, creating, and building with the traditional classroom and laboratory setting. Students observe, record, question, seek additional information, and – through creative and insightful thinking – solve problems that are important to them. The focus of the course is wide in scope dealing with the fundamentals of ceramics, glass, metals, polymers, and combinations of these materials – namely, composites.

Students use a wide variety of written resources, including current scientific journals, technical reports, and textbooks to obtain information about the materials studied. They use writing not only to record observations, procedures, and experiments, but also as a tool for thinking about, studying, and learning the subject matter. They interact with others to learn how group dynamics are essential in today's workplaces.

Guest speakers, including technicians, scientists, engineers, and artisans provide information or demonstrations to broaden the students' understanding of materials science. Tours are scheduled to nearby laboratories and production facilities.

The course is designed to meet local educational requirements for technology education, vocational education, and science.

The three Oregon and three Washington high schools now pilot testing and developing materials for MST, under a U.S. Department of Education demonstration grant, include Gladstone, Corvallis and Churchill (Eugene) in Oregon, and Bellevue, Kennewick/Kamiakin and North Thurston in Washington. Columbia Basin College in Pasco also is testing the curriculum in a community college environment.

New sites are required to implement these essential features:

✓ an advisory committee representing each of the four broad fields,

✓ experts willing to work with students in the schools, and

✓ teacher inservice training including industrial hands-on experience.

New kinds of equipment are required – such as annealing ovens, precision measuring equipment and hardness testers – but many items already may be available in chemistry, physics, and vocational metals and woods labs. Teachers – preferably a technology and a science teacher working together – will typically build the course from their own interests, strengths, and experience incorporating existing school and community resources.

# Materials critical in modern world

This introductory course in materials science is designed to be unique in several ways.

First, the scientific knowledge content is that of materials, rather than physics, chemistry, biology or botany, which are more often the introductory subjects of science. Yet materials are critical everywhere in our modern technological world, and tomorrow's citizens need explicit knowledge about these materials.

This introductory course also is unique because it goes beyond "passing on knowledge" about a subject in science. Instead, students are exposed to knowledge about the subject while they are in the process of solving problems in the execution of a project. Learning comes from solving problems using the scientific process, speeded by scientific knowledge. Students independently observe, record, question, seek additional information, and, through creative or insightful thinking, solve problems that are important to them.

Moreover, materials become the medium for art and handicraft pursuits and are thus appealing to a broad range of students. This appeal motivates students to persevere through a problem-solving experience to produce their designed material. In addition, the degree of "handiness" developed by each student in the course goes a long way toward instilling a sense of self-confidence: The student accomplishes what he or she sets out to do.

A goal of the course is to provide an understanding of the highly socialized undertaking known today as science. Simulating that environment in the classroom can instill in students an appreciation for the power of being able to use scientific knowledge to solve problems, no matter what vocation they may pursue. They learn that aspect of the scientific process involving vision and imagination as well as the excruciating work of following a step-by-step process. By actually seeking to make an object – perhaps a ring or a stained glass piece – to an envisioned degree of excellence, the student seeks knowledge and creatively solves or circumvents problems as they are encountered.

And every now and again, some of the students, in the course of their lives, will have an opportunity to add to that body of knowledge we call materials science and technology. A few may become scientists, but others may choose equally important paths as engineers, technicians, welders, silversmiths, electronics specialists, mechanics, orthopedic surgeons, dental assistants, auto body repairers, glazers, fiberglass molders, potters, interior designers, bricklayers, or sous chefs.

All can benefit from this foundation.

"Materials become the medium for art and handicraft pursuits, and are thus appealing to a broad range of students. This appeal motivates students to persevere through a problem-solving experience to produce an object of choice."

# Outline of course content

I. Introduction

A. Materials – The basic nature and properties of materials are explored.

B. Solid State – Materials can be divided into two general categories: crystalline and amorphous.

II. Body of Course

A. The Nature of Metals - Such properties as luster and conductivity flow from the metallic bond.

B. The Nature of Ceramics - Ionic and covalent bonds render ceramics hard, brittle and resistant to heat.

C. The Nature of Glasses - Glasses are amorphous materials. How do they avoid being crystalline?

D. The Nature of Polymeric Materials - The chainlike molecules of polymers form both amorphous and crystalline arrays.

E. The Nature of Composite Materials - Two materials can be combined to obtain properties that neither has by itself.

III. Topics Integrated

A. Physical Properties

1. Thermal Properties of Materials - Heat is conducted through materials by the particle-like waves known as "phonons."

2. Electrical Properties of Materials - There is a wide spectrum of properties, from the best electrical conductor to the best insulator.

3. Strength of Materials - All materials are characterized and used according to demonstrated abilities to withstand stress.

"Some of the students, in the course of their lives, will have an opportunity to add to that body of knowledge we call materials science and technology."

III. Topics Integrated (continued)

B. Additional Properties of Materials

1. Chemical Properties - reactions that are familiar in liquids also take place within solids.

2. Magnetic Properties - The same magnetism of a strong magnet resides in the magnetism of single electrons.

3. Optical Properties of Materials - What is the basis for such properties as transparency, opacity and laser action?

C. Application of Materials - Deeper knowledge of materials gives freer rein in the economics and selection of appropriate materials for a designed product.

D. Periodic Table of Elements - When the elements are arranged by atomic number, a repetitive or periodic pattern of properties appears.

E. Significant Developments in the History of Materials.

F. Methods of Scientific Inquiry.

G. Vocational Application--What are the occupations where a knowledge of materials is essential?

**Important Note:** This course does not utilize a pre-packaged curriculum or support media such as are available for the nationally-developed Principles of Technology, Applied Biology/Chemistry, Applied Math, or Applied Communications programs. Rather, it hinges on a process that draws on the skills of trained faculty (preferably a team composed of science and technology teachers) using the unique resources of that school and community.

"By actually seeking to make an object...the student seeks knowledge and creatively solves or circumvents problems as they are encountered."

# Student learning objectives

On completing the course, the student will be able to:

1. Identify materials specific to our environment.
2. Classify materials as metallic or non-metallic.
3. Classify materials as crystalline or amorphous.
4. Understand the basic properties of materials (i.e., mechanical, electrical, thermal, chemical, optical, and magnetic).
5. Understand that the properties of a material are governed by chemical bonding and crystal structure.
6. Understand that the properties of materials can be altered by changing their chemical makeup or by treating them in various ways.
7. Be able to use particular terms specific to materials science and technology
8. Understand the basic processes of extracting, preparing, and producing materials used in this course.
9. Select materials for specific uses based on their properties, characteristics, and service.
10. Apply scientific observation and precise measurements to analyze properties of materials.
11. Flourish in an environment of creativity.
12. Think critically to solve problems in manipulating and controlling the materials used in this course.
13. Use writing to record observations, procedures, and experiments, and as a tool to think, study, and recall the subject matter.
14. Demonstrate in writing and in group discussion an appreciation and understanding of significant developments in the history of each material area studied.
15. Select, design, and build a project(s) demonstrating the creative application of materials science processing.
16. Describe occupations which hinge on knowledge and manipulation of materials.

"The degree of 'handiness' developed by each student in the course instills a sense of self-confidence: The student accomplishes what he or she sets out to do."

# Instructional Approach/Process

The full-year course includes units of study on each of the following materials: metals, ceramics/glasses, polymers, and composites. Each unit of study includes the following activities:

✔ Experiments conducted by the students individually and in groups

✔ Demonstrations and lectures by the instructor or guest speakers

✔ Project development with students designing, researching, creating, and building individual or group projects

✔ Visits and tours of industries and laboratories supplemented by videos and guest speakers

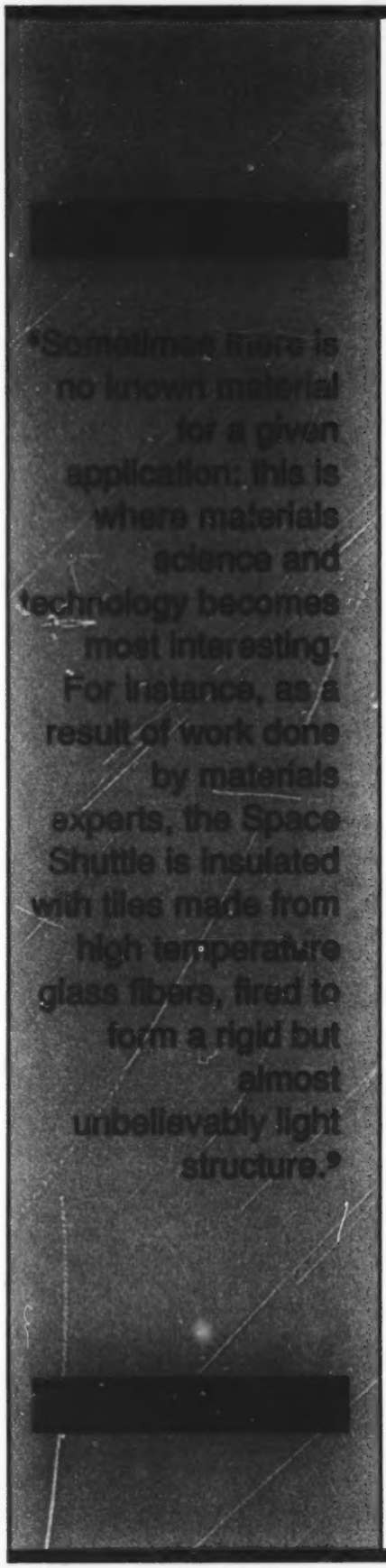
Integrated throughout each unit of study will be the following activities and learning experiences:

✔ Writing and sketching in a journal to record observations, procedures and experiments, progress on projects, and responses to demonstrations, lectures, guest speakers, tours, readings, and films

✔ Reading and researching (through interviews, periodicals, and library resources) in relation to the unit of study or the student's selected projects

✔ Exploring through discussion, writing, and application the process of creativity, innovation, and scientific inquiry as it occurs in the workplace

On the following pages are two excerpts from the typical MST teacher's instructional plan. The MST curriculum builds from the teacher's own resources and knowledge supported by local industry and community expertise. These two sample activities should be viewed as part of a continuum of experiences and not as isolated lessons any teacher can use to fill time.


"Sometimes there is no known material for a given application; this is where materials science and technology becomes most interesting. For instance, as a result of work done by materials experts, the Space Shuttle is insulated with tiles made from high temperature glass fibers, fired to form a rigid but almost unbelievably light structure."

# Iron wire demonstration introduces students to world of materials science

The iron wire demonstration is an excellent way of introducing the physical properties of expansion and contraction, electrical conductivity, and phase changes in the solid state.

Additions and variations to these concepts are:

✔ measuring the actual expansion and contraction of various materials,

✔ rating materials in the order of their ability to conduct electricity,

✔ and the "solid state change in metals" experiment found in the curriculum.

A variation to the use of a variac in this experiment is the use of a carbon pile, as found in an automotive battery load tester, in series with several 12 volt batteries. This has proven very useful and easier to locate in schools since this equipment is located in most high school automechanics laboratories. The use of a welding power supply has not been varified as a means of providing power, but would be worth investigating to see if it can be used.

Other metals and materials can also be tested in the same manner as the iron wire to observe their physical properties as an electric current is applied to them.

Oxidization can be observed on the surface of the used (heated) iron wire. Discussion of property changes because of oxidization is in order as are oxidization/reduction reactions and refining of raw materials.

Rigid foam is cut in industry using a similar set-up to the iron wire demonstration. Discuss and/or experiment with the best material for cutting the foam. Why is iron not a good choice as a "cutting" tool? What properties are needed in a material to act as an appropriate blade to cut foam?

## Learning objectives

This experiment, in the heating and cooling of ordinary iron wire, leads students to understand much of the fundamental nature of metals and how they behave. Learning objectives of the metals segment of the curriculum addressed through this experiment include:

✓ Explain and describe the crystalline structure of metals.

✓ Define metallurgical terms such as crystal lattice, solid solution, and phase change.

✓ Explain how metallurgy is used in the machining trades.

"The demands of modern technology are dramatically changing the world we live in. The need for new materials with special mechanical, physical and chemical properties is critical."

## Science related learnings

Students can learn to calculate the coefficient of thermal expansion for a variety of metals and compare these to data provided in the *Handbook of Chemistry and Physics*. Ohm's Law becomes surprisingly easy to understand as they actually witness voltage pushing current through a resistance. This unit can be concluded with a quick look at an iron/carbon phase diagram, commonly used by machinists and heat treating specialists.

## Technology related learnings

In earlier days, the hardening of metals relied on recognizing certain colors of the metal, at certain temperatures. These colors can be researched in *Machinery's Handbook*, and perhaps drawn using pastels or colored pencils. From there, the "moods" that various colors evoke can be discussed. The differences between "cherry red" and "straw" and the temperatures they represent are among the topics that could be discussed.

In addition, a comparison of the hardening and annealing characteristics of plain iron wire, silver wire, and copper can be made as they are used in jewelry applications.

## Vocational related learnings

Students, individually or in small groups, can research the *Dictionary of Occupational Titles, Occupational Outlook Handbook*, and *Standard Industry Classification Manual* to locate occupations in Metal Manufacturing: metal machining, powder metal fabrication, forging, heat treating, high tech explosive forming techniques.

## Use of community experts

Volunteers from the community or visits to occupational settings to expand this learning activity might by found by contacting local jewelers, welders, foundries, machine shops, dental labs, and electronics repair facilities.

## Journal Entries

Here is a perfect time for the student to deal with the concept of "discrepant events," inconsistencies in observed behavior. Examples include:

"I think it's normal for a wire to sag as it is heated, but why did it suddenly contract?"

"Can this heating and cooling occur over and over?"

"How could I perform a meaningful test?"

"A drawing of the experimental set-up would be appropriate."

"Diagrams of crystal structure would also help illustrate how the atoms are in different crystalline arrays before and after the phase change."

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"I want them to learn that it's OK to make mistakes. I want them to learn the value of writing. I want them to learn the value of observation. I want them to learn the value of math, science, English, and technology."

*-- Steve Plippo*
*Richland High School*

# Reports from the field

Students find meaning
in MST classrooms
from Bellevue
to Eugene

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# MST: Meeting the needs of students and industries

## *Joint effort sparks regionwide improvements to meet changes in society*

*"In the future, firms will find themselves much more dependent on the imagination and innovation of their workers. From the shopfloor to the executive suite, companies will look for employees who are adaptable to sweeping change in their jobs."*
**– Northwest industrialist**

In high schools from Richland, Washington, to Eugene, Oregon, the face and form of occupational education is changing to meet the demands of the American workplace.

In the past, industry required – and schools produced – workers who knew how to follow orders, perform simple tasks, and to work independently – in short, they could get the job done with a limited amount of guidance from their employer.

Today, American industry is clamoring for workers who can think critically, work cooperatively, trouble-shoot problems, and creatively overcome workplace obstacles.

Today's workers are confronted with a dizzying rate of discovery and new application in the materials of their trades – the plastics, glass, metals, and wood products. And today's schools face the challenge of bringing modern materials technology into the classroom.

"America's race to retain world leadership in production and manufacturing is in jeopardy unless technicians and skilled workers understand the nature and application of materials that are dramatically changing our world," says Larry McClure, director of NWREL's Education and Work program. "Yet few secondary and postsecondary vocational technical programs are prepared to deal with the advent of new materials in today's workplace."

NWREL is part of an innovative effort to develop materials technology curriculum and school/industry partnerships in a demonstration project with Battelle Pacific Northwest Laboratories, Richland (Washington) High School, Central Washington University, Columbia Basin College, and high schools in Oregon and Washington. Funded by the U.S. Department of Education, school district matching funds, and private industry, the project is entering its second year of implementing and testing a vocational skills development model that can be used to prepare new workers in dozens of occupational areas and to update the skills of workers in traditional crafts and trades.

The materials technology cooperative demonstration project is an outgrowth of a joint venture between Richland Public Schools and Battelle. Together, Richland teacher Steve Piippo and a team of Battelle scientists, technicians, and engineers created a secondary education curriculum prototype – materials science and technology – which was field tested at seven high schools last year. The curriculum, which had been in use at Richland High School, was tested at North Thurston, Sammamish, and Kennewick and Kamiakin high schools in Washington; and Churchill, Gladstone and Corvallis high schools in Oregon.

Battelle's contribution to developing the curriculum was funded primarily through a

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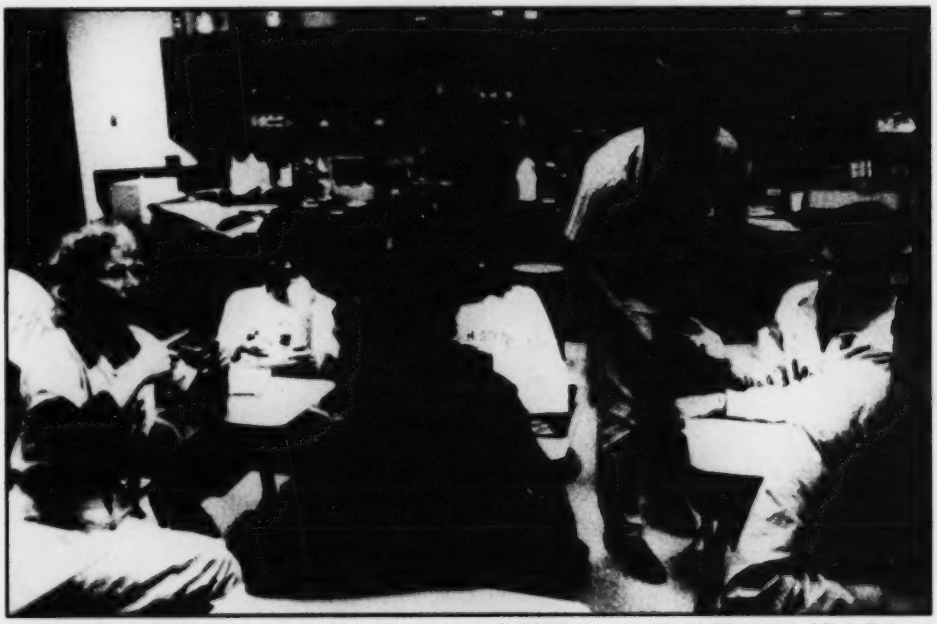

**Teacher Andy Nydam (right) works with students in MST class at North Thurston High School in Olympia, Washington, while woman at left signs lesson for hearing-impaired student.**

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# Team teaching, student collaboration part of MST project

Continued from previous page

federally supported Science Education Center, which includes school/industry partnership programs such as Sharing Science with Schools and the Teacher Research Association (TRAC) program.

Batelle's goal is to enhance teachers' background and awareness in science, math, and technology, says Irene Hays, manger of Batelle's Science Education Center. This is particularly true in materials science, which is at the cutting edge of advances in scientific research and development. "We want to ensure that teachers have the background, materials, and resources to prepare the next generation of the technical workforce," she says.

Bruce Hawkins, director of vocational education for the Tri-Cities area, says: "I see materials science as becoming a large focal point for technical training for the next 10 to 20 years. The materials science program at Richland High School will become, if not a national model, a model throughout the Northwest."

In the December 1989 edition of *The Technology Teacher*, Richland teacher Steve Piippo wrote that the MST course was unique in several ways, including:

- Its use of materials science as its foundation
- Its appeal to students with a variety of interests, backgrounds, and aspirations
- Its acceptance to satisfy academic requirements (credits) for both technology education and lab science
- Its use of a scientific approach to problem solving
- Its use of resources from the academic, business, and industrial communities.

The MST curriculum does not rely on textbooks with neatly furnished outlines, experiments, questions, and answers. Rather, it engages students and teachers in a process of discovery that relies on team teaching, student collaboration, risk-taking, experimenting, success, setbacks, creative thinking, and perseverance.

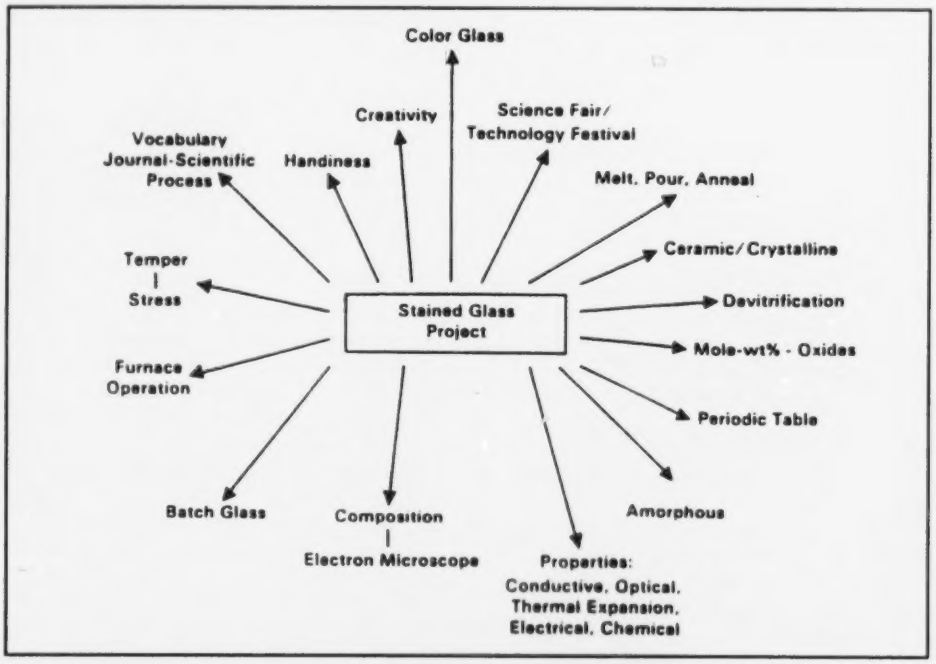
Such a curriculum comes none too soon for the dynamic changes occurring in the American workplace and the increased interdependence of global markets.

"As the work of our nation becomes more and more technical, even jobs that have typically been filled by individuals with limited skills and education now require workers with basic academic competence," writes B. June Schmidt in a report from the National Center for Research in Vocational Education, *Proceedings for Forum on Integrating Occupational and Academic Education*. "Thus, helping students develop this competence has surfaced as a major concern for educators, one that requires a collaborative commitment of both occupational and academic faculty.

"Preparing today's students without academic basics can be compared to attempting to use a car without fuel or, in times past, a carriage without a horse. Both college-bound and noncollege- bound students need occupational as well as academic preparation to meet workplace demands."

NWREL's role in the MST project has been to provide technical assistance in project management, evaluation, and dissemination.

The following report from the field shows some of the frustrations and rewards of the first year of MST implementation. It was prepared by Tony Kneidek, a writer/editor/photographer with NWREL.




**Stained glass project showing integrated learning concepts**

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# Richland: Home of Materials Science & Technology

*Steve Piippo sparks movement that inspires public education changes*

Richland High School teacher Steve Piippo is on a roll. Piippo, considered by many to be the father of materials science and technology in the public schools, is nothing if not passionate when addressing his prized MST curriculum. MST courses, well-established at Richland, must now be recognized by colleges and universities as legitimate transfer credits for science students, Piippo says.

"MST is as valid as biology," Piippo says. "In biology, you dissect frogs. In MST, you dissect materials."

Piippo's MST classroom reflects what is at the heart of the MST curriculum — experimentation, risk-taking, and working together. Signs proclaim, "It's okay to err!!," "What did I do today?," and "Who did I work with and what was the result?" In the classroom, students discuss experiments, raise questions, hypothesize results, and trouble-shoot problems.

In Piippo's MST lab, students work cooperatively on a variety of projects, from setting a magenta stone in a ring to blowing glass to centrifugal casting. MST, Piippo says, is about experimenting, creating, designing, and building.

It is an interdisciplinary course that combines science, crafts, engineering, and mathematics. It is, Piippo adds, "technology education for the future."

And in Piippo's MST class, writing is a critical part of the curriculum. Experiments account for 50 percent of students' grades, and student journals account for the other 50 percent.

"Anytime we can get students to write outside of the English class, it lends legitimacy to what we do," Piippo says. "We use a model of the working notebook — the real scientist's notebook. It's a place to experiment, to hypothesize.

"I want them to write about all the successes, all the bobbles, all the screw-ups. If something doesn't work, they can go back to their journal and find out why."

The journals are a way for students to better understand and communicate the work they are doing. In Piippo's class, the journals must be complete. "If I walk out of here and get hit by a bus and killed, another guy should be able to pick up my journal and continue my work," he says.

Piippo works with Jim Deatherage, chair of the English department and past Washington Teacher of the Year, on journal writing skills.

The collaboration, they agree, has helped bridge the gap between materials sciences and the liberal arts. "If you're a teacher, you're supposed to want to learn," Deatherage says. "And if you want to learn, you've got to open your mind."

**Steve Piippo reviews project with students in MST class.**

Piippo, a member of the Richland class of '70, says he was teaching "traditional woodshop" and other industrial crafts classes when he interned at Battelle Pacific Northwest Laboratories (PNL) in Richland. The partnership continued through the school year as Piippo began to develop a new curriculum that combined creativity, handiness, and scientific knowledge. Soon, PNL and others offered technical assistance and other resources for Piippo's MST curriculum.

The class, Piippo notes, appeals to a broad range of students. "If you're a science type, you can apply what you know. And if you're a hands-on type, you get to learn some of the scientific concepts behind your ability to create."

Piippo's students are given freedom to experiment, to make mistakes, to share information, and to creatively overcome problems. "Creativity," Piippo says, "becomes addictive." It could well be the motto for his MST classes.

Upon completing the MST courses at Richland, Piippo wants his students to know about the family of materials and how they apply in today's changing workplace and world.

"But there are also the intangibles," he says. "I want them to learn that it's OK to make mistakes. I want them to learn the value of writing. I want them to learn the value of observation. I want them to learn the value of math, science, English, and technology."

It's a lot to ask, but Piippo expects a lot from his students. "It's a magical kind of thing that happens here," he notes. But the class is not for everyone. "If you're not a dutiful student," Piippo says, "you're doomed."

# Human relations get boost in Olympia

Meeting the challenges of the 21st century

## *MST curriculum attracts students from different walks of life*

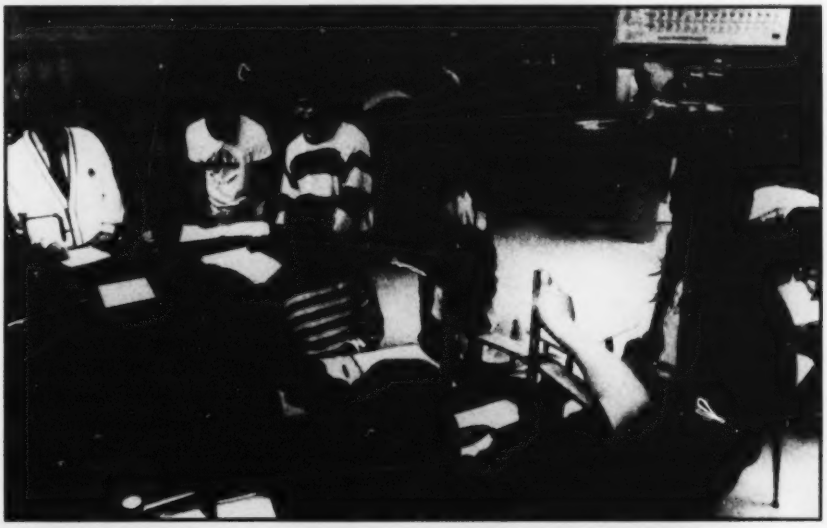
At North Thurston High School near Olympia, students are learning a lot more than they bargained for in their Materials Science and Technology course.

Certainly, there are the hands-on experiments with wood, glass, polymers, and other materials. Yes, there is frequent journal writing that chronicles activities, raises questions, documents observations, notes setbacks, and celebrates successes. And, of course, teachers Len Booth and Andy Nydam engage students in lively discussions that encourage creative thinking and problem solving.

So what else is there? There is, say Nydam and Booth, the "human relations" aspects of a class that unites students from diverse backgrounds and varied learning styles in a common goal. The MST class represents a true cross-section of the student population at North Thurston: there are resource center students, middle-of-the-roaders, top achievers, and a hearing impaired girl who attends class with her interpreter.

"With a heterogeneous group like we have here, there are more questions raised and there's more interaction among different groups of students," Booth says. "One student may be weak in journal writing but skilled in the hands-on work. And he can share that skill with other students. There's a different kind of learning going on here. They're learning to work with one another."

The MST curriculum has been embraced at North Thurston by Booth, a science teacher, and Nydam, an automotive technology teacher. The two work in a classroom neatly cluttered with the gadgetry of experimentation. Students "destructively test" the breaking point of different types of wood on a crude, but functional, contraption consisting of two bathroom scales, a hydraulic jack, and braces.



**Students test the breaking point of wood in North Thurston MST class.**

Phil Nelson, a retired materials scientist from Boeing, is a frequent visitor to the classroom who is impressed with the simplicity of some of the equipment used to conduct experiments.

"Afterall," asks Nelson, "what did Galileo have? What did Pascal have? Look at what they accomplished. You can do an amazing amount of work with materials and equipment that are readily available."

Students in the MST class at North Thurston are doing just that. "There's an incredible amount of learning that can take place with some backyard materials," notes Nydam. "Sometimes we overlook that. Part of the advantage of this class is that students can apply it to everyday life. Too often, classes make you successful in school, but not in the real world."

And, adds Booth, the MST curriculum provides a creative outlet while enhancing students' problem-solving skills. "It's nice to have an experiment where we tell the students that we don't know what the outcome will be. We want them to come up with their own answers."

Students, too, see differences in the MST course and others they have taken. "This class is definitely different from other science courses I've taken," says one senior. "It has more lab time and more practical application than other classes. And the lab experiments aren't pre-determined. We're learning by doing and developing answers as we go along."

The class requires students to take risks and to expose themselves in group discussions, shared journal entries, and class presentations. Booth and Nydam encourage that risk-taking.

"We're not concerned about being ridiculed in here," Booth says. "We're concerned about learning."

"I like the whole area of materials science and technology. This class is a good cross between chemistry principles and practical experiences."

Larry Alvarado, Sophomore
Kamiakin High School

# MST in Kennewick: Learning is 'a lot more fun'

## *First year of program both frustrating and fulfilling*

Dustin Gerlach, a sophomore at Kennewick High School, uses steel prongs to gingerly remove a red-hot metal cup from an annealing oven set at 2000 degrees farenheit.

Gerlach's thick gloves, heavy leather jacket, head and face shield, and tentacle-like pincers give him the eerie look of a space-age lab technician as he pours a stream of molten glass into a cross-shaped form. The thick liquid oozes like honey into the form, where it hardens quickly into a homemade craft.

"I like it," Gerlach says proudly as he removes his protective gear. "It beats working with just woods and metals."

Welcome to the world of materials science and technology, a marriage between the sciences and vocational education classes that is designed to more effectively prepare students for the rapidly changing workplace.

There was a time, notes Kennewick High School teacher Tom Staly, when employers sought employees who could follow orders, not ask questions, and just get the job done on a day-to-day basis.

Today, though, with rapid changes in the American workplace and with increasing interdependence on global markets, workers must understand the nature of materials. They must be able to respond to problems as they arise. And they must be able to work well with others.

The time is right, Staley says, for the MST curriculum. "All the students were learning before (MST) was how to manipulate materials," Staley says. "But there was no understanding of what was happening to the materials under different conditions. Now, we're able to take the students into a whole new realm of materials technology."

Just ask Julia Niezgoda, a junior in Staly's MST course. "I've learned about plastics," she says. "I learned how to make glass and jewelry. And I've learned a lot about wood — the different grains, the different glues to use, the water resistancy of various types of wood. This class is a lot of experimentation and a lot of hands-on stuff. It's a lot more fun."

Staley, who has taught in the Kennewick School District for 12 years, has just completed the first year of the MST curriculum. "I'm definitely a believer," he says.

Staley says the class will help students to become better employees and better consumers in the future. "I want these students to become more technically literate, and I have no doubt that this program does that."

Across town at Kamiakin High School, Dave Speakes has struggled to get the MST curriculum off the ground. The first-year teacher was awaiting equipment and other resources during the course's first semester last spring. Speakes did not let the setbacks dampen his spirits.

In one makeshift experiment, students made one mixture of corn starch and water and another of flour and water. They then went outside to "play catch" with their concocations and to note the different qualities of the two mixtures.

Back in the classroom, Speakes had them discuss and write about their observations. "I want you to write down and brainstorm ideas," he told them "I want you to talk with each other about it. This is your time to think about why the materials responded differently to water and how the materials could be used."

Speakes was looking forward to the fall, when ovens, casting equipment, and other resources would be available to students.

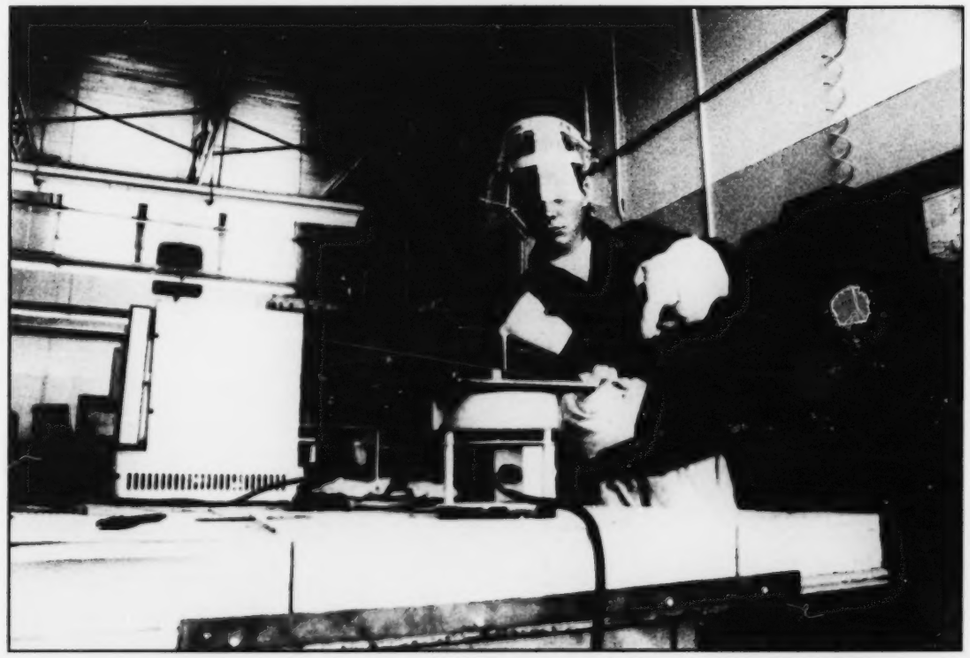
Students, though, find the course meaningful despite the problems. "I like the whole area of materials science and technology," says Larry Alvarado, a sophomore who also takes advanced chemistry classes. "This class is a good cross between chemistry principles and practical experiences."

Adds sophomore Pat Habschman, "I like the opportunity to work with my hands. The course is different from a crafts class. We learn more about the materials, and we experiment more with them."

At Kennewick High School, Staly says he anticipates growth in the MST curriculum. And that, he adds, will be a welcome change and have a positive influence on students.

"In the old days," he says, "you'd hand kids a sheet with instructions on it, give them some materials, and let them go.

"I think this approach is much more meaningful for the kids," he adds. "They gain an understanding of what is happening with the materials, as well as the practical experience of working with them."



Dustin Gerlach of Kennewick High School pours molten glass into a form during an MST class.

# Team teaching: Essential for success of Corvallis MST

Corvallis students combine classroom lessons with practical experience.

For Noel Stubbs and Eric Pittinger, team teaching is a necessity in creating an effective and successful materials science and technology course.

"We've been insistent on team teaching," notes Stubbs, a vocational education teacher at Corvallis High School. "It would have been physically impossible to teach the course the way we have with less than two instructors."

The problem, Stubbs says, is also the beauty of the course. At any given time, students will be staining glass, growing crystals, soldering, pouring molten glass, and involved in a variety of other projects. It takes two teachers just to keep up with the activities and the questions that arise for students.

"The other part of team-teaching," he says, "is the marriage of chemistry and occupational technology. My chemistry is over 20 years old. It's Greek to me. But Eric does a beautiful job with it."

Pittinger, the science side of the teaching team, says he would not be able to teach the MST course alone because he has not had the practical experience that Stubbs shares with students. "I get some hands-on when I teach chemistry, but not the real application," he says.

That has changed with the MST class. "There was nothing comparable to this before other than a chemistry class," Pittinger says. "But chemistry was not the type of hands-on approach that we have here. When students were done with a chemistry experiment, they would pour it down the drain. Here, they keep their experiments."

Pittinger and Stubbs good-naturedly refer to themselves as Doctor Frankenstein and Igor. "Eric is the mental, and I'm the hands," Stubbs says. "The beauty of it, though, is that Eric is learning the occupations and I'm learning the science."

Both teachers are in the classroom daily, and they share lecture responsibilities as well as guiding students through practical applications of what they've learned. The team teaching approach helps break down barriers that have long existed among occupational educators and academic teachers. At Corvallis High School, the barrier also is physical: the vocational labs are across a creek from the main campus.

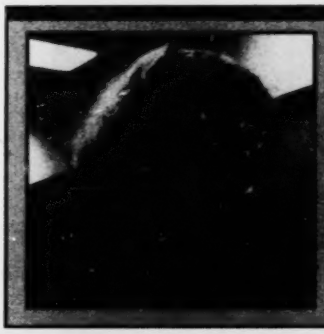
"For me, industrial arts were always the people across the creek," Pittinger notes. "Teaching this course with Noel has done a lot for both of us and for the kids. They see the combination of the two of us working together and it breaks down barriers for them, too."

Last year was the first time the MST course was offered in Corvallis. Despite delays in getting equipment, Pittinger and Stubbs kept their students busy with lectures/discussions, projects, and journal writing. Writing is an important part of the curriculum, Stubbs notes.

"I agree with Steve Piippo in Richland," he says. "If students can't write, if they can't communicate what they know, then all the knowledge is useless. It needs to be understood to be shared."

Melanie Mahan, a senior art student, says the MST curriculum addresses issues that are important to all students. "There's so many combinations of materials that haven't been explored, and there's so many possibilities to create," Mahan says.

"The possibility of combining different materials into new art forms is endless," she adds.



"In my future as an artist, the possibility of combining different materials into new art forms is endless."

– Melanie Mahan, senior, Corvallis High School

**Material Sciences & Technology**

Meeting the challenges of the 21st century

**August 1990**

# MST: Meeting the challenges of rapidly changing industries

The world of work, Don Michael will tell you, is changing.

"The new industries out there aren't calling for your traditional welder or your traditional woodworker," says Michael, a technology education and metals teacher at Gladstone High School near Portland. "They're looking for high-tech welders – people who can work with plastics and new composites.

"They're looking for people with more of a science background, somebody who can solve problems. And, I'd have to say, they're looking for a more craftsy person as well."

Enter the materials science and technology curriculum. Michael was lead teacher in the MST course during its inaugural year at Gladstone. In addition to covering glass making, glass staining, and centrifugal casting, he sprinkled in heliarch and plastic welding and silver soldering.

The idea, he says, "is to expose students to the nature and properties of materials." For example, students in Michael's MST class discuss the cooling of glass, the different components of glass, and how to change the properties of glass.

As in other MST classrooms in Washington and Oregon, though, the lessons do not end there. Students then have the opportunity to make their own glass, shape it, heat it, cool it, stain it, and gain the practical experience of working with the materials from their raw stage to finished product.

Bill Stewart and student in Gladstone MST lab.

"This class will expose the students to the tools, equipment, and materials that will elevate their creativity and confidence," Michael says. "I want them to be aware that there are many jobs in industry that are related to the use of sophisticated materials. What we're doing in here is relevant to what is happening in industry."

During the first semester, Michael team taught the MST course with biology teacher Bill Stewart. But Stewart's time was reduced considerably because of other obligations, and that, Michael says, presents problems.

"MST is really an applied chemistry class," he says. "I've gotten a lot of support here from the science department. But to teach this the way it's intended to be taught takes a team approach."

Stewart says two teachers are necessary to explain the physical properties of materials to the students as well as to guide them during their lab experiments.

"I'm not a vocationally experienced person," he says, "but I can help out when the kids get bogged down on projects. And two people can do that four times as fast as one person. It's not an arithmetical progression. It's geometric."

Teacher Don Michael and students review notes.

This year, Michael hopes to strengthen student journal writing skills by working with an English teacher, to invite more guest speakers from industry to talk with students, and to attract a broader range of students to the course.

The first year of the MST curriculum was challenging, rewarding, and sometimes frustrating, he says. A more structured curriculum, videotape for classroom use, and development of scope and sequence would be helpful.

But the MST curriculum, Michael says, is here to stay. "It takes about two or three years to get a new course on the ground," he notes. "It's all coming together now. It'll go smoother next year, then smoother still the year after that."

**Materials Science & Technology**

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# Churchill MST relies on team teaching concept

## *'With two of us, we can hit off each other'*

In team taught materials science and technology courses, not just the students do the learning.

At Churchill High School in Eugene, Oregon, manufacturing technology teacher Larry Brace and science teacher Don Michelson have been team learners as well as team teachers. "I really doubt seriously if you could pull this sort of curriculum off without both teachers – the vocational type and the science type – to rely on each other," says Brace. "With two of us, we can hit off each other. When one of us runs out, the other can fill in. And some of the areas we get into, hell, we don't know anything about them."

In the MST curriculum, where there is a heavy reliance on both the physical make-up of materials and how to use them, team teaching takes on added importance.

Without it, teachers rely on what they know best rather than integrating the two disciplines. "When the first shot's fired," Brace says, "you fall back to what you know. If I was doing this alone, I'd teach only a third of what Don's doing."

At Churchill, the commitment to team teaching appears firm. And Brace and Michelson also share a common planning period to prepare for the MST course.

Such coordination has paid off in the classroom, where Brace and Michelson have recruited a good cross section of the student population. MST students at Churchill rotate one day in the classroom and one day in the lab. And, Brace says, students experimented with polymers, metals, ceramics, woods, and glass for six weeks before deciding on a project in one of those areas.

**Larry Brace works with a student in Eugene MST class.**

The idea is to expose kids to a variety of activities, to broaden their horizons, and to encourage them to try things they haven't done before.

"There's no big loss in failure," Brace says. "Some of the things we try work, and some of them don't. But the kids see that it's a process of discovery, and that's what's important."

Students are graded daily on their lab work, and their journals are collected every two weeks and graded. Students also turn in daily progress reports on their activities.

"We give them lots of science," adds Michelson. "I want to show the kids that science is fun. These students are asking so many questions that we can't keep up with them. And that's what teaching is all about."

Senior Robert Clevenger found the MST course helpful in his efforts to build remote control cars. For years, he has built the cars for himself and friends. "You need to know the mixtures of materials," he says. "You need to know how light they are, how they hold up under stress, and how they hold up under heat. In this class, I've learned more about how materials are structurally and physically put together. The class did exactly what I hoped it would do, and more."

At Churchill, students also have benefitted from frequent visits from industry representatives. Weyerhaeuser Corp., Spectra Physics, and other companies have taken an interest in the MST course.

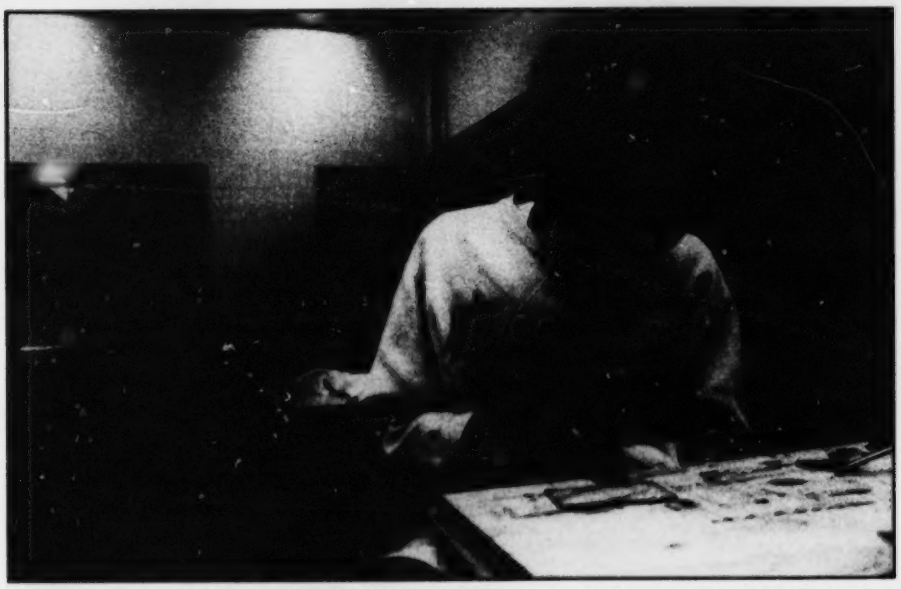
Journal writing, too, is a critical element in the MST course. "It's a discipline in itself," Michelson says. "Keeping a journal is not a new concept. Whether you're a doctor or a lawyer or a scientist, you keep a journal."

Students also find the journal writing helpful. "In the long run, I learn a lot more by writing things down," says junior Megan Dockendorf. "I can refer back to my journal entries, and it's better for recalling information."

Michelson and Brace have been recruiting students for this fall's MST course, and hope to have 50 participants in two sections, both team taught. "There's no shortage of things to do," Brace says. "It's a matter of deciding what it is you're going to be able to teach, and what you're going to leave out."

Meeting the challenges of the 21st century

# Combining thinking skills with hands-on experience



Students work on stained glass projects in MST course at Sammamish High School.

At Sammamish High School in Bellevue, Washington, lead materials science and technology instructor Bud Smith sees the emerging MST curriculum as a way to prepare students for the rapidly changing world of work.

That world will require employees to be skilled problem solvers, to be able to work cooperatively with others, to trouble-shoot difficulties on the job, and to critically assess workplace situations to make on-the-spot decisions.

"My goal," says Smith, "is to increase the reasoning skills of the students. If they have a question, if I hear them say, 'I wonder what happens if ...,' I tell them let's try it and see."

The first year of the MST curriculum has proven time consuming and challenging for Smith and Ron Bielka. Bielka, a science teacher, and Smith, who teaches basic auto and metals, team up once a week to teach the MST class, with Smith handling teaching the rest of the week.

"It really amounts to a whole lot more than we ever expected planning-wise," notes Bielka. "I think that's to be expected in the first year a class is offered. It's particularly true with MST because nothing is in the books. We've depended on a big Xerox budget."

MST staff at Sammamish has been hampered by a major remodeling that has forced the class into temporary, makeshift quarters. Because the space was unsecure, all equipment and material had to be removed each evening and set up again the next day.

"We've been scrambling to find the resources to use in the classes," says Smith. "We're still trying to get it together." Nonetheless, students have been introduced to an initial "take apart" project, stain glass work, making glass and plywood, and other activities.

Bielka says he would like more science students to enroll in the course to gain additional experience in applying their skills in the classroom. "I'd love to have more of my science students see that there is a rational thought process to scientific experimentation," he notes. "A lot of these kids could grow up to be technicians, and the thought process for technicians is equally as important as it is for the scientist."

Smith says that in the future, employees will need to know more than simply how to put materials together. "We're trying to get the kids to do a little more thinking," he says, "to go along with the hands-on experimentation.

"One of the biggest strengths of the MST curriculum is the practical application of the materials. You have to know how different materials work, what they are made of, what they can or can't do, and when to use them. That's what we're trying to teach," Smith says.

*"My goal is to increase the reasoning skills of students. If they have a question, if I hear them say, 'I wonder what happens if ...,' I tell them to try it and see." — Bud Smith*

"Learning comes from solving problems using the scientific process, speeded by scientific knowledge."

# METALS

## Demonstration: Iron Wire

### Student Learning Objective:

At the conclusion of the demonstration, the student will be able to:

- ✔ Explain and record the effect of electron conduction in metals to a change in physical state (heating)
- ✔ Observe the phenomena that occurs in all materials when they are heated and cooled (expansion and contraction)
- ✔ Observe the physical change in solid materials when they alter their crystal structure (phase change)

### Materials:

- ✔ Iron wire, bailing wire is recommended
- ✔ Power source - Variac (variable transformer) and power leads, 15-20 amps desirable, though smaller amperage can be used if patience is used and dial is turned at proper speed to a known limit of the fuse
- ✔ Two portable ring stands
- ✔ Weight
- ✔ "C" clamps to mount the ring stands

### Procedure:

1. Suspend the iron wire between two portable ring stands a minimum of 15 feet apart, with weight suspended from the middle of the wire. **This must be performed on a non-conductive bench or table!**

2. Apply electrical leads from the Variac to each end of the wire near the ring-stand connections.

3. Slowly increase voltage across the wire and observe any changes that occur. Observe the movement of the weight during this same time.

4. The obvious color change in the wire is an indication that the wire is heating up with increased current (electron flow) in the wire.

5. Reduce voltage rapidly while again observing the weight attached to the wire.

## Demonstration: Iron Wire (continued)

6. The continuous movement of the weight demonstrates thermal expansion/contraction. The brief, discontinuous change in weight movement demonstrates the point at which a crystalline phase change occurs.

7. The effects can be more readily observed by placing a ruler next to the weight to measure the shift. Notice that the change is not only reversible but repeatable.

   The phase change that is occurring is as follows:

| | Temperature Range | | Volume |
|---|---|---|---|
| $\alpha$ - Fe (Ferrite) | Ambient | 912°C | B.C.C. Less Dense |
| $\gamma$ - Fe (Austenite) | 912° | 1394°C | F.C.C. More Dense |
| $\delta$ - Fe ($\delta$ - Ferrite) | 1394° | 1538°C+ | B.C.C. Less Dense |

B.B.C. = Body-Centered Cubic
F.C.C. = Face-Centered Cubic

'Vibration causes the atoms to move a greater distance apart in three-dimensional space.'

## Safety Precautions:

**********

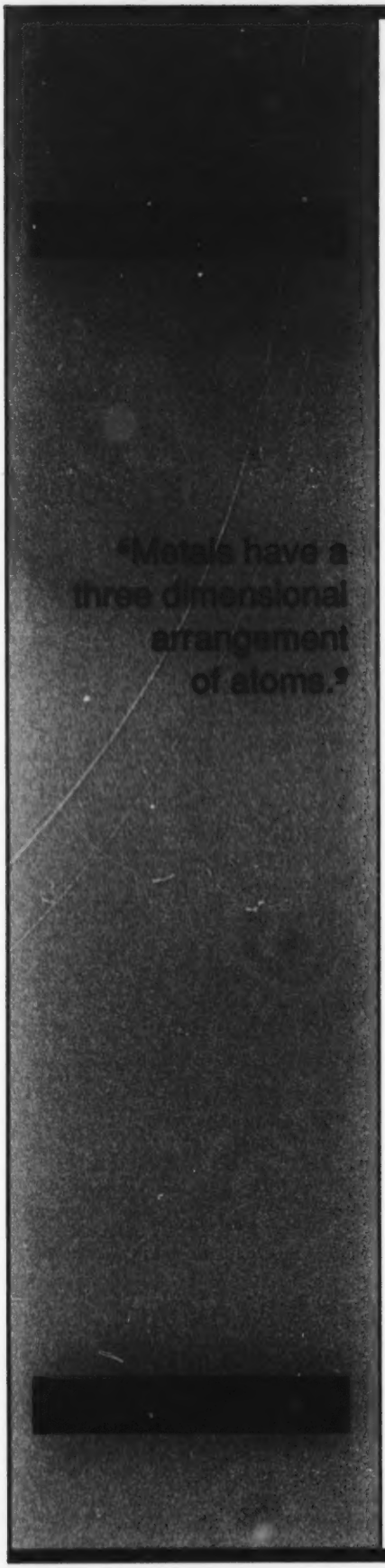
**WARNING: The wire, when hot, can cause burns and even a fire!**

**********

## Instructor Notes:

A. When a voltage is applied across a conductor, electrons are caused to move through the conductor much like water moves through a pipe. As the electrons collide with atoms, energy is given off in the form of heat; the greater the voltage - the faster the electrons - the more energetic the collisions - the greater the amount of heat generated.

B. When materials are heated, the atoms that make up the material will vibrate to a greater extent the hotter they get. This vibration causes the atoms to move a greater distance apart from each other in three dimensional space, and results in what is referred to as "thermal expansion." When the heat source is removed, the vibrations will decrease, and the atoms will "contract" to their original positions.




## Notes:

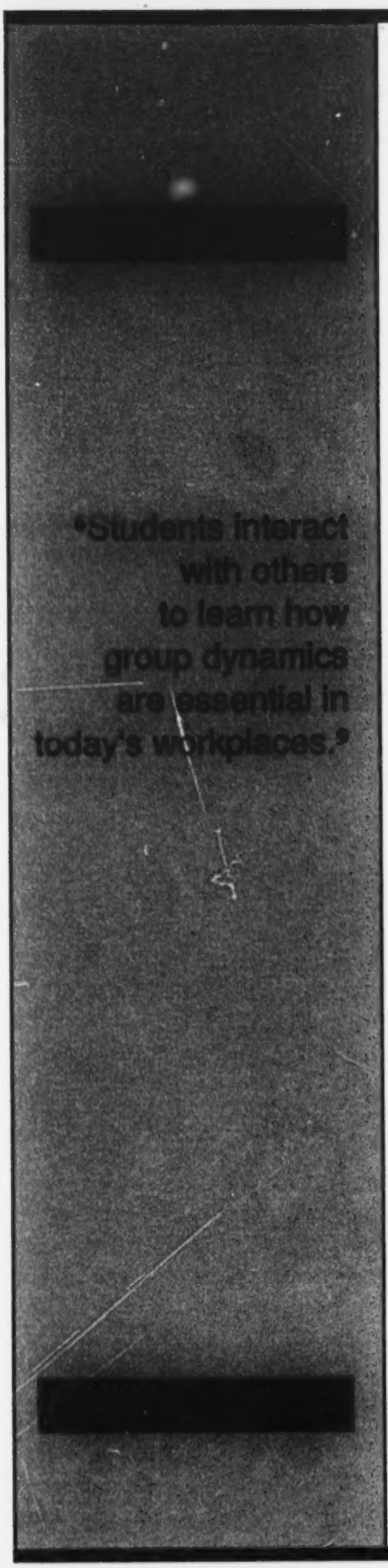
1. The type of "crystal structure" a material has is dependent upon many factors such as atom size, type of atoms, temperature, to name a limited few.

2. Metals, such as the iron wire used in this demonstration, have a regular, repeating, three dimensional arrangement of atoms known as a "crystalline structure."

3. Many "crystalline" materials will have the same "crystalline structure" over the entire temperature range as you heat it from room temperature to melting, i.e., aluminum.

4. Other materials, notably iron, may assume one "crystalline structure" at room temperature and other "crystalline structures" at different temperatures. This behavior is known as polymorphism or allotrophy. (Poly = many; morphism = shapes or forms)

5. As a polymorphic material is heated, at some given temperature the atoms making up the crystal structure will realign themselves to the new crystal structure. If the volume occupied by the atoms in these two different crystal structures is different, the solid material will undergo a physical change when the change from crystal structure #1 to crystal structure #2 takes place. (As demonstrated during the heating of the iron wire.)




# Dragon's tear experiment introduces students to cooperative learning strategies

Prior to this experiment, students will have been experimenting with some of the physical and chemical properties of glass. Experimentation could include melting individual compounds to see at what temperature they melt, how they react to heat, and how they solidify. Students could also experiment with a binary glass (two component glass), making a simple phase diagram of their findings and noting eutectic areas and perhaps unique compositional areas. Students could also make simple soil melts to create a simulated obsidian. This process can be accomplished with Twenty Mule Team Borax mixed at varied weight percents in soil to find a glass that possesses the best possible characteristics of obsidian at a given melt temperature. Yet another experimental process is to vary components of a three to four component glass observing the varying effects on the glass. The list of experimental glass melting is not exhaustive, but limited only by time and depth of inquiry.

Following the demonstration, students could examine other materials that develop stress lines while being observed under light polarizing film (i.e., clear plastics, drinking glasses, plate glass).

Using plastic (polymeric materials), students could also examine how stress centralizes at flaws in materials. These flaws become the area of materials failure.

## Learning objectives

This experiment in the making of "Dragon's Tears" helps to satisfy the learning objectives for this unit on Glasses and Ceramics. Some of these objectives include:

- ✓ "Know, give examples, and experiment with mechanical, chemical, thermal, nuclear, optical, and electrical properties of glass."
- ✓ "Describe aspects of the glass industry."
- ✓ "Be able to melt, pour, anneal, and temper a batch of glass."

## Science related learnings

The instructor will be able to introduce the concepts of conduction, radiation, and convection. This can be followed by locating the various colors of the glass, as it is heated, on a chart of the electromagnetic spectrum. Concepts of viscosity/density/specific gravity can be woven into the discussion as the glass finally melts and is ready to pour. Convection currents are noted as the Dragon Tears enter the beaker of water. Finally, as students begin cutting the "tails" off the Tears, concepts of hardness/strength/brittleness/toughness can be dealt with. How polarizing film is manufactured can also be discussed.

"Newton's Rings experiment involves students viewing refraction through a microscope using two microscope slides and a human hair."

## Art related learnings

Glass, with its shiny and often iridescent surfaces, leads nicely into a study of iridescent glass. An iridescent surface can be formed on glass as a decoration, and it is often found on old glass exposed to the elements. What is iridescence? These thin oxide coatings on the glass lead to discussions of refraction. Basically, this action can be illustrated with a prism. The prism can be used to illustrate the various light spectra contained in sunlight, fluorescent and incandescent light. A simple "Newton's Rings" experiment can involve students now viewing refraction through a microscope, using two microscope slides and a human hair!

## Vocational related learnings

In this study of glass, students would be able to research the *Dictionary of Occupational Titles, Occupational Outlook Handbook,* and the *Standard Industry Classification Manual* to locate occupations related to glass-processing. This could then lead into either field trips or "teams-of-two" interviews to local dispensing opticians or auto glass installers. "What machines are used to measure, cut and grind the glass?" "What are some of the tricks of the trade?" Students could then actually complete a "Resistance of Glass Containers to Chemical Attack" test as outlined in the ASTM C-225. This would provide the students actual experience performing industrial quality control occupational experience.

## Journal Entries

Throughout these learning experiences, students would be writing in their journals: questions to ask, data from the experiment, ponderings/possibilities/dreams, mistakes or errors, and certainly tinkering, stumbling, and flights of fancy.

- ✔ "Does it make any difference what kind of cutting tool I use on the Dragon Tear?"
- ✔ "Can I cut off a lot or very little?"
- ✔ "What new glass product can I make that uses this principle?"

## Learning Strategies

Not only will students work in small groups in an experimenting mode, but they can conduct research on occupational references and perhaps prepare an audio or video tape on their findings. Cooperative learning strategies work particularly well here because only if there is real cooperation and sharing of knowledge, will the Dragon Tears form correctly!

## Use of Community Experts

Volunteers from your local community who might be able to assist with this activity include potters, glass blowers, glass makers, glazers, dispensing opticians, stained glass artists, and many more.

"Materials are critical everywhere in our modern technological world, and tomorrow's citizens need explicit knowledge about these materials."

# GLASSES AND CERAMICS

## Experiment: Dragon Tears

### Student Learning Objective:

At the conclusion of the experiment, the student will be able to:

- ✔ Produce a "Dragon Tear."
- ✔ Successfully cut the dragon tear in order to demonstrate the effect of tempering and internal stresses.
- ✔ Observe effects of stress in glass with use of light polarizing materials.

### Materials:

- ✔ Melting furnace
- ✔ Crucible
- ✔ Metal tongs
- ✔ Stainless steel beaker (4 to 5 liter capacity)
- ✔ Safety eye glasses
- ✔ Scissors
- ✔ Wire cutters (diagonal-cut pliers)

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**WARNING: Wear safety glasses for this experiment**

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### Procedure:

1. Melt a $Na_2O * B_20_3 * 2Si0_2$ glass composition (approximately 50 grams) in the furnace at 1100°C for one-half hour. Clear glass works best for this experiment.

2. Remove the molten glass from the furnace and slowly pour, drop by drop, the glass into the beaker containing cold water. Long fibers trail from each droplet of glass and at times need to be clipped with scissors at the mouth of the crucible.

3. When glass becomes too viscous to pour, return crucible to the furnace for approximately 10 minutes. Step 2 can then be repeated or the glass may be air-quenched.

## Experiment: Dragon Tears (continued)

4. Sometimes many glass droplets need to be made before establishing the approximate size of the "tear" that will hold its shape. The size of the droplet is determined by the viscosity of the glass which should flow like warm honey before attempting to pour any glass droplets. If the glass is too liquid, lower the furnace temperature 25 to 50 °C. To cool the glass in the crucible so that it will thicken to the consistency desired, rotate the crucible from side to side so that the glass flows and mixes evenly as it cools.

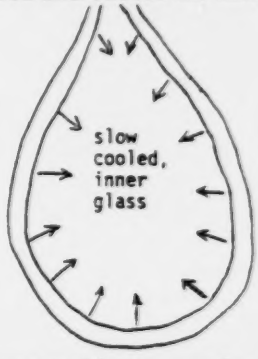
5. Remove droplets with their long trailing fiber from the beaker. Hold the droplet in one hand and begin cutting the fiber at the farthest point from the droplet using diagonal-cut pliers. Continue cutting the fiber, moving progressively closer to the droplet. The tempered glass droplet will explode into sand size particles in your hand as the cutting approaches the thicker portion of the fiber.

"Glass does not break while in compression."

## Notes:

1. Tempered glass droplets are formed from the rapid cooling of the droplets skin. The water rapidly hardens or solidifies the outer layer of the glass but the middle of the droplet is still molten or viscous. As the inner glass losses heat and solidifies, its atoms are able to pack closer together and the glass shrinks. This shrinking draws the hardened, outer glass into a smaller area and causes the skin to be tightly compressed.

Fast cooled, hard, thin glass skin is pulled into a smaller area than it is comfortable in. →




As the inner glass evenly pulls in the outer skin, tremendous forces upward to 50,000 psi (347 Mega Pascal [MPs]) develop. Since glass does not break while in compression, these high compressive forces will remain stable. But by clipping the thick part of the glass tail, the cracking of the glass disrupts the equilibrium of the glass forces and a chain reaction of cracking occurs throughout the entire glass droplet. The result: a tremendous amount of stored energy is released very rapidly.

## Notes: (continued) _____

2. Many of our glass materials are tempered to give them special properties: Plate glass in car windows and sliding glass doors are made to shatter when broken so people will not be hurt by large, sharp, jagged, flying glass pieces. Glass is also tempered to increase its strength since external loades or forces must overcome compressive forces engineered into the glass before stress begin to effect the surface of the glass. Industry tempers its glass by cooling the molton glass surface with jets of cool air.

3. Stress can be observed in glass with light polarizing film and/or polarized sunglasses. By placing the polarizing material on both sides of the glass and rotating one piece of the polarizing material, colorful patterns can be observed where there is stress. Do this with a dragon tear and observe the intense rainbow of colors seen throughout the glass. For best effect do this over an overhead projector so that the bright light will better illuminate the stress lines.

4. Anneal one of the droplets by placing it in a cool annealing furnace, heating it to approximately 450°C for two or three hours, and then let it cool in the furnace overnight. Observe the effects of an annealed glass droplet using the polarized materials.

# Students, educators cite need for MST curriculum

*Washington, Oregon participants agree that time is right for change*

*"Few secondary and postsecondary vocational technical programs are prepared to deal with the advent of new materials in today's workplace."*
*Larry McClure, director*
*NWREL Education & Work*

*"We want to ensure that teachers have the background, materials, and resources to prepare the next generation of the technical workforce."*
*Irene Hays, manager*
*Science Education Center*
*Battelle*

*"I see materials science becoming a large focal point for technical training for the next 10 to 20 years. The materials science program at Richland High School will become, if not a national model, a model throughout the Northwest."*
*Bruce Hawkins, director*
*Vocational Education*
*Tri-Cities*

*"It's a magical kind of thing that happens here."*
*Steve Piippo, teacher*
*Richland High School*

*"This class has more lab time and more practical application than other classes. And the experiments aren't pre-determined. We're learning by doing and developing answers as we go along."*
*Senior*
*North Thurston High School*